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The Resources Agency

Department of Water Resources

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PROGRESS REPORT SAN JOAQUIN VALLEY DRAINAGE INVESTIGATION QUALITY AND TREATMENT STUDIES THROUGH DECEMBER 31, 1967

BIO-ENGINEERING ASPECTS OF AGRICULTURAL DRAINAGE

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RONALD REAGAN
Governor
State of California

WILLIAM R. GIANELLI
Director
Department of Water Resources

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

RONALD REAGAN, Governor, State of California
WILLIAM R. GIANELLI, Director, Department of Water Resources
JOHN R. TEERINK, Deputy Director

SAN JOAQUIN DISTRICT

Carl L. Stetson . . . . . District Engineer
G. Donald Meixner . . . . . Chief, Planning Section

This report was prepared under
the direction of

Louis A. Beck . . . . . Chief, Quality and Treatment Unit

by

Thomas A. Tamblyn . . . . . Assistant Engineer, Water Resources

ABSTRACT

This report describes the progress made through December 31, 1967 in quality and treatment studies of the Department's San Joaquin Valley Drainage Investigation. The work described was done alone and in cooperation with the United States Bureau of Reclamation and the Federal Water Pollution Control Administration. In addition, work planned for the future is outlined.

The work completed or in progress is summarized as follows: (1) the quantity of agricultural waste water to be removed from the basin has been determined; (2) the concentrations of most constituents of this waste are known; (3) additional work is being done on the pesticide, nitrogen, and phosphorus content; (4) nitrogen removal studies have begun because of the concern over what effect drainage discharge will have on the environment; and (5) two treatment methods are being developed--algae stripping and anaerobic denitrification.

INTRODUCTION

Centuries ago, man learned to divert water and irrigate his land. However, he did not recognize the need to dispose of the salt laden waters that resulted from this irrigation. Many of the fertile lands that were irrigated by ancient man had to be abandoned because of the accumulation of salts in the soil.

The ancient irrigators were in no way unique. In West Pakistan, salinity and water logging problems, which have developed during the last 20 to 40 years, have caused approximately 30,000 acres of land to go out of production each year. In our own state, the early farmers of the Imperial Valley did not provide for land drainage, and many of them went bankrupt.

The San Joaquin Valley is not immune to drainage problems either. Many sporadic attempts have been made to resolve them on a local scale since the early 1900's. None of these attempts resulted in the necessary master plan for the removal of salt from the basin. When the waters of the San Luis Unit of the Federal Central Valley Project and of the State Water Project are applied to the lands of the Valley, the drainage problems will multiply and intensify.

The purpose of this report is to describe the progress made through December 31, 1967 in quality and treatment studies of the San Joaquin Valley Drainage Investigation. The work described was done by the Quality and Treatment Unit, Planning Section, San Joaquin District Department of Water Resources (DWR); alone, and in cooperation with the U. S. Bureau of Reclamation (USBR) and the Federal Water Pollution Control Administration (FWPCA). In addition to explaining what progress has been made, work planned for the future is outlined.

As various segments of the investigative work are completed, additional bulletins in this series will be issued, with a final report coming out in 1970. The final report will summarize all of the various segments and make recommendations for future courses of action. Starting in 1968, annual progress reports will be issued as supplements to this report.

In 1957, the State Legislature authorized the San Joaquin Valley Drainage Investigation as a result of studies of drainage problems and water quality degradation in the San Joaquin Valley by a Joint [State] Legislative Committee on Water Problems. The purpose of the investigation is to determine the magnitude of the drainage problem in the Valley and to develop a solution for it. Three phases of this continuing investigation are; (1) collection and evaluation of the basic data needed to define the potential waste-water-disposal problem areas; (2) estimates of the quantity and quality of waste waters, and (3) evaluations of alternative methods of disposal.

The quality and treatment studies of the investigation include; (1) determining the nature of the material that must be removed from the basin; (2) predicting water quality changes within any disposal facility that might be constructed; and (3) determining what effect the discharge of the waste water will have on the ecology of the area near the discharge. Because of the nature of the waste waters and the possibility of undesirable effects at the discharge point, studies to determine the practicability of treating the waste water to prevent detriment as a result of an agricultural waste discharge, have been undertaken as a joint venture by DWR, USBR, and FWPCA.

PROGRESS THROUGH DECEMBER 31, 1967

Early in the investigation, the many and varied factors that led to the drainage problems in the San Joaquin Valley were analyzed. The results of this analysis indicated that the most feasible method of protecting the agricultural economy of the Valley was to remove the highly saline agricultural waste (drainage) water from the basin.

The potential drainage problem areas (Figure 1) cover approximately 1,700,000 acres of the Valley. An estimated 1,210,000 acres of this land will be irrigated by 1990--with 1,150,000 acres irrigated now.

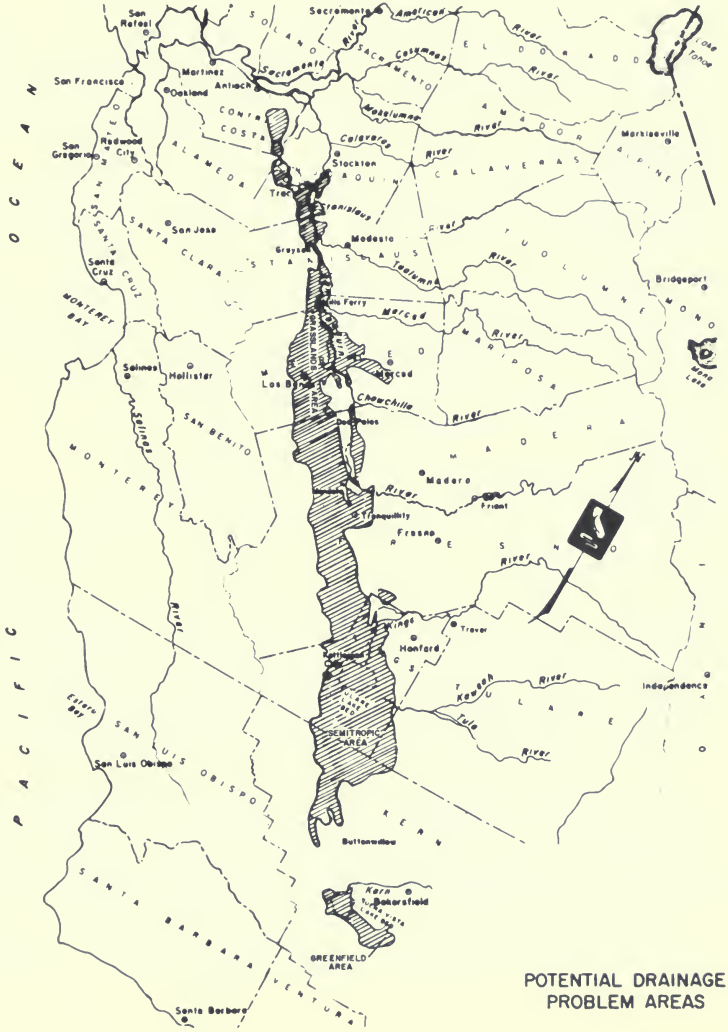
Quantity and Quality of Agricultural Waste Water

The expected quantities of saline agricultural waste water have been predicted using a mathematical model of the basin. The model also predicted the future total dissolved solids (TDS) and sodium (Na) content of the waste. In order to determine and predict the chemical constituents of the waste, other than Na, the DWR conducted an extensive surveillance program from May 1959 through October 1964. Samples of shallow ground water, surface water, tile drainage and surface drainage were taken throughout the Valley. The main emphasis of this program was placed on the major cations and anions. The resulting predictions from this program are summarized in Table 1.

Since October 1964, the surveillance program has been continued to refine the estimates and to observe how the quality of subsurface drainage water changes with time and season. The continuing surveillance program for mineral and other constituents is not as extensive as it was prior to October 1964.

The surveillance program and the studies of the effects of drainage discharge on the receiving waters (to be discussed later in this report) made it apparent that additional information was needed on pesticides and nutrients (nitrogen and phosphorus).

FIGURE 1



DEPARTMENT OF WATER RESOURCES SAN JOAQUIN DISTRICT 1967

TABLE 1
ESTIMATED CONSTITUENT CONCENTRATIONS IN
SAN JOAQUIN VALLEY AGRICULTURAL WASTE WATERS

Chemical Constituents	Concentrations in mg/l	
	Initial	After 50 yrs. of operation
Minerals		
Calcium	220	160
Magnesium	160	90
Sodium	1,900	540
Potassium	20	10
Carbonate	0	0
Bicarbonate	220	200
Sulfate	3,500	740
Chloride	1,000	670
Nitrate	90	90
Boron	11	3
Total Dissolved Solids	6,800	2,500
Non-Time Varying Constituents		
Nutrients		
Total Nitrogen	21	
Total + Organic Phosphate	0.35	
Pesticides	<0.001	
Others		
Dissolved Oxygen	5-10	
5 Day B.O.D.	1-3	
C.O.D.	10-20	
Sufactant (ABS)	0.0	
Phenolic Material	0.001	
Grease and Oil	0.5	

Pesticides. The term "pesticides" is a broad reference to substances or mixtures of substances intended to be used for controlling, preventing, destroying, repelling, or mitigating any pest. It includes insecticides, fungicides, rodenticides, herbicides, vermicides, defoliants, wood preservatives, etc. The San Joaquin Valley is one of the major centers of pesticide use in the United States The use of such substances for crop protection is widely practiced and is likely to continue at an increasing rate as new lands are brought into production.

When the investigation started, it was thought that the waste waters transported from the basin might possibly have high concentrations of pesticides and, therefore, cause problems in the area of discharge. Until late 1963, the best method available for monitoring the pesticide content of water was the carbon absorption technique. This method required the installation of expensive equipment at each sampling station and an involved series of extractions at the laboratory, which, in the San Joaquin Valley, did not produce significant quantitative results. Therefore, relatively few samples were taken in conjunction w the 1959-64 surveillance program. The relatively few samples did indicate occas ally the presence of pesticides in the waters of the Valley.

A special pesticide monitoring program was begun in the fall of 1963, when a private laboratory contracted to determine pesticide contents by the micro-coulometric gas chromatographic technique. This analytical technique does not require expensive installations at the sampling stations and yields significant quantitative results. In 1966, the Department of Water Resources' Laboratories obtained gas chromatography equipment. Since that time, pesticide samples have been analyzed by the Department.

The pesticide monitoring program initiated in September 1963 covers many of the waters of the State. Table 2 presents a summary of the data collected through December 1967. Analyses of these data have indicated that the pesticide content of the material to be removed from the San Joaquin Valley is not significantly higher than that of the surface waters in the areas of possible disposal.

The pesticide program will be continued on a reduced scale for another two or three years. The purpose of continuing the program is to check for changes that might result from increased usage of pesticides, new compounds, or saturation of the soil column by the material and an eventual breakthrough to the subsurface drainage systems.

TABLE 2

SUMMARY OF WATER-BORNE CHLORINATED HYDROCARBON PESTICIDE PROGRAM FINDINGS
(concentrations in parts per trillion 1/)

Type of Station	1963-64 2/			1965			1966			1967		
	Times Sampled	Times Detected	Avg. 3/ Conc.	Times Sampled	Times Detected	Avg. 3/ Conc.	Times Sampled	Times Detected	Avg. 3/ Conc.	Times Sampled	Times Detected	Avg. 3/ Conc.
Central Valley Subsurface Drains	16	15	406	50	48	197	105	78	150	121	48	44
Central Valley Open Drains	73	67	888	115	115	1,606	76	72	1,453	95	34	5,777 4/
Central Valley Surface Waters	232	189	141	158	154	145	198	172	56	60	28	26
Bay Area Surface Waters	32	27	98	49	49	93	28	23	37	12	9	14

1/ Summation of identified pesticides. 2/ 16 months, September 1963 through December 1964.

3/ Average Concentrations calculated without considering samples in which no chlorinated hydrocarbons were detected.

4/ Value biased by 2 highly concentrated samples, probably caused by accidental spill of pesticide.

In addition to monitoring the waters of the Valley, the Department is cooperating with several other federal, state and local organizations on studies taking place on two test plots. At the test plots, known quantities of pesticides are applied to the surface of the soil. Samples of the applied water, the tile drainage, the surface runoff, and the soil are taken and analyzed. With this information, the fate of the applied material can be determined The first report on this work has been issued by the Department as Bulletin No. 174-1, "The Fate of Pesticides Applied to Irrigated Agricultural Land".

Nutrients. A nutrient is any substance that furnishes nourishment to promote growth. In agricultural practice, nutrient supplements are generally added

by use of one or more of the numerous commercial fertilizers now on the market In Valley agricultural waste waters the most significant nutritive elements ar nitrogen (N) and phosphorus (P).

Both of these elements have been shown, on occasion, to be limiting growth factors for aquatic life. That is, nitrogen or phosphorus may be prese in natural waters in such low concentrations that they are the factors in the environment that limit the amount of growth that can take place. If excessive quantities of N or P are added to the waters of an area in which the element added is limiting, the ecology of that area will be changed. This change is often for the worse.

A monitoring program is being conducted to determine the concentrati of nutrients present in the waste waters that must be removed from the basin. This program is designed to determine how the concentrations of N and P vary w season, soil type, and agricultural practice. With the information gained fro this work, and that from other studies, the removal of waste water from the Sa Joaquin Valley will be accomplished without causing a detriment to the area of ultimate disposal. Table 3 presents some of the information gathered to-date part of this nutrient monitoring program.

TABLE 3

NUTRIENT MONITORING PROGRAM SUMMARY
AVERAGE 1967 CONCENTRATION IN SAN JOAQUIN VALLEY BY AREA
(in milligrams per liter)

	North	Central	South
Subsurface tile drainage			
Nitrate as nitrogen	7	33	11
Phosphate as phosphorus	0.12	0.09	0.64
Irrigation water			
Nitrate as nitrogen	4.5	3	4
Tailwater			
Nitrate as nitrogen	7.5	5.8	5.4

Effects of Discharge. If the solution of one problem creates a new problem, that solution must be revised. To be more specific, if in attempting to solve the drainage problems of the San Joaquin Valley a new problem is created at the disposal site, the original problem will not have been solved. It will have been merely modified and relocated.

When it was determined that the drainage problems of the Valley would best be solved by transporting the agricultural waste waters out of the basin, the Department immediately began studies of the effects of these waters on the ecology of the possible disposal sites. The majority of the work on the effects of drainage disposal was done as a part of the Departments' "Delta and Suisun Bay Water Quality Investigation". The final report of the investigation, Bulletin No. 123, was issued in August 1967. The Sacramento District of the Department of Water Resources is also doing some work related to the effects of drainage disposal. This work is being done as part of their studies to predict future conditions in the Delta.

The results of the various studies of the effect of drainage disposal on the Bay environment indicate that nitrogen has the most significant problem causing potential. With careful operation of drainage facilities, no significant TDS increase will result in the receiving waters. In fact, the release of drainage water, under certain circumstances, will have a beneficial effect on the TDS content of the water in the area of discharge. The pesticide content of the water to be removed from the basin is essentially the same as that of the waters in the area of the proposed discharge. The calculated concentration increases caused by the other constituents of agricultural waste water will not have an effect on the environment. Therefore, the Department is undertaking studies of methods of removing nitrogen from drainage water.

Treatment

Treatment of waste agricultural drainage water for nitrogen removal is necessary to avoid excessive enrichment of the receiving waters which may cause an undesirable increase in algal growth.

The Department originally proposed to study treatment by the algae stripping method. This proposal has been expanded and there now is an Interagency Nitrogen Removal Treatment Group (DWR, USBR, and FWPCA) jointly studying several processes and corollary factors.

Algae Stripping. Because of this concern over the effects of nitrate enrichment, the Department entered into an agreement in November 1963 with Doctors Oswald, Crosby, and Golueke, specialists in bio-engineering processes. The purpose of this agreement was to determine the feasibility of using biological treatment techniques as a means of removing objectionable constituents from drainage water. As a result of this work, a program of pilot-scale studies has been implemented to determine the most efficient method of operation of the biological treatment process recommended; algae stripping.

Construction of a pilot-scale (50 gallons per minute) treatment facility (Figure 2) will be completed in January 1968. The facility is located near Firebaugh, California, in western Fresno County, and is a part of the "Interagency Agricultural Waste Water Treatment Center". The Center will be described more fully later in this report. Upon completion of construction, studies will begin to determine the optimum operating criteria for the process.

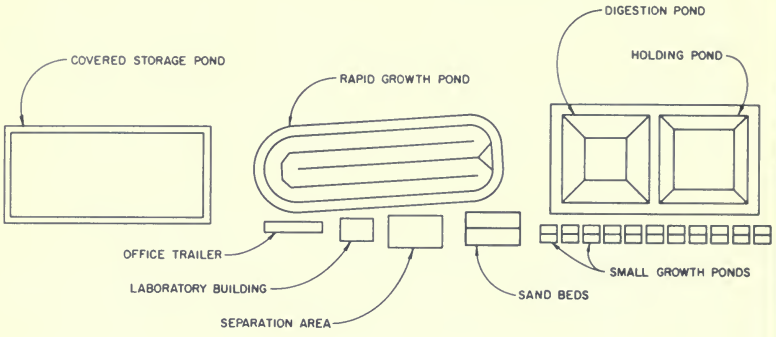


Figure 2. PLAN OF ALGAE STRIPPING PILOT PLANT

The studies will involve varying environmental conditions in "rapid growth ponds" to maximize the growth of algae in drainage water. The algae grown will incorporate the nitrogen present in the water into their cell structure. Once the algae have taken the nitrogen into their cells, they will be harvested--thereby "stripping" the nitrogen from the material to be exported from the basin. Methods of separating the algae from growth pond effluent will also be studied.

The nitrogen removal studies must be completed by January 1970. This is a short period of time in which to optimize the algae stripping process --only two irrigation seasons. To ensure that adequate data are generated during this period, approximately twenty small growth ponds will be constructed to supplement the pilot-scale rapid growth pond. They will be operated in units of three or four to study how the variation of individual parameters, such as depth, detention time, and phosphate addition affects algal growth. When the individual parameters are optimized for maximum algal growth in the small ponds, they will be combined in the large rapid growth pond to determine if there is any antagonistic effect between parameters. Prior to this time, the rapid growth pond will be used as a source of supply for the separation studies.

Harvested algae probably have a monetary value as cattle feed, soil conditioners, etc. Some studies have been conducted at University of California at Davis and other agricultural research centers to determine the food value of algae. A study will be made of what return might be expected from the sale of algae produced at a treatment plant.

A final report on the algae stripping process will be completed by the end of the 1969-70 fiscal year.

Anaerobic Denitrification. Although the algae stripping process appeared to be the most feasible technique of nitrogen removal in 1964, the Department was not satisfied that it was the only practicable technique. During Fiscal Year 1965-66, Dr. Perry L. McCarty prepared a report on the "Feasibility of the Anaerobic Denitrification Process for Removal of Nitrate Nitrogen from Agricultural Drainage Waters". The process proposed by Dr. McCarty involved adding an organic carbon source to the drainage water. The mixture is then passed through a container in which an anaerobic environment (a relatively oxygen-free environment) is maintained. In this container, bacteria reduce the nitrate in the drainage water to nitrogen gas, as they are oxidizing the organic carbon supply. The nitrogen gas escapes to the atmosphere.

The containers used for the original work on this process were closed vessels. However, deep ponds, submerged rock or sand beds, or packed columns may do as well or better. Studies are currently being made on the use of deep ponds and packed columns. The preliminary deep pond work is being conducted by the Department at the Interagency Agricultural Waste Water Treatment Center near Firebaugh. The packed column work was initiated in Pomona, California, at the FWPCA advanced waste treatment installation and is now being carried on in Firebaugh. The results of these two studies will be used for the design of a pilot-scale anaerobic denitrification plant at the Treatment Center. This plant will be constructed in early 1968 by the FWPCA. Results of the Department's deep pond work will soon be available as Bulletin No. 174-3.

Interagency Agricultural Waste Water Treatment Center. Upon receiving the report on the feasibility of the algae stripping process, the Department began looking for a suitable site to construct the recommended pilot-scale plant. An agreement was signed on September 14, 1966, with the USBR for the use of a strip of land along the right-of-way of the Delta-Mendota Canal near Firebaugh.

In November of 1966, the FWPCA requested permission to occupy a small area of the algae stripping pilot plant site. This area would be used to study the feasibility of reclaiming agricultural waste water through the use of desalination techniques. From this beginning, the Interagency Agricultural Waste Water Treatment Center has grown.

The original plan to share the Department's algae stripping site has proved inadequate. Since that time the FWPCA has arranged with the USBR to use segments of the Delta-Mendota Canal right-of-way immediately north and south of the Department's segment.

The FWPCA's Southwest Region released a report on the effects of agricultural drainage disposal on the San Francisco Bay and Delta (the proposed disposal site) in January 1967. As a result of this report, the USBR and FWPCA have become actively involved in nitrogen removal studies. Prior to the report, they were assiting the Department through financial assistance and technical cooperation. However, since its release, they have become activ partners. This participation is illustrated by Figure 3, the organization cha for the Treatment Center and,Table 4, the proposed budgets for studies relate to treatment of agricultural waste water.

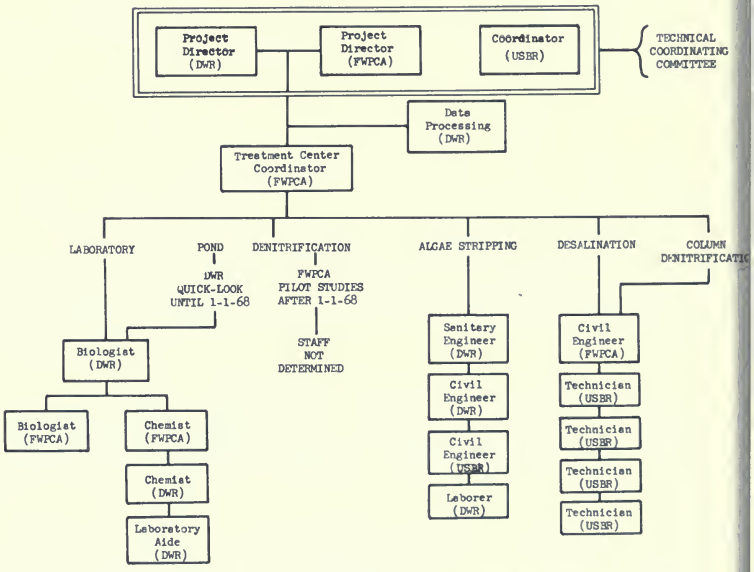


FIGURE 3. ORGANIZATION CHART - AGRICULTURAL WASTE WATER TREATMENT CENTER

TABLE 4

PROPOSED BUDGETS FOR STUDIES RELATED TO
TREATMENT OF AGRICULTURAL WASTE WATER

Project	Participating Agencies	Fiscal Year Budget Estimates 67	68	69	70	Total
Develop algae	DWR	80,000	82,500	82,500	45,000	290,000
stripping	FWPCA	70,000	100,000	75,000	-	245,000
process	USBR	120,000	138,750	138,750	87,500	485,000
						$1,020,000
Develop pond	DWR	-	-	-	-	-
denitrification	FWPCA	-	200.000	200,000	100,000	500,000
process	USBR	-	-	-	-	-
						$ 500,000
Develop column	DWR	-	-	-	-	-
denitrification	FWPCA	25,000	50,000	-	-	75,000
process	USBR	-	-	-	-	-
						$ 75,000